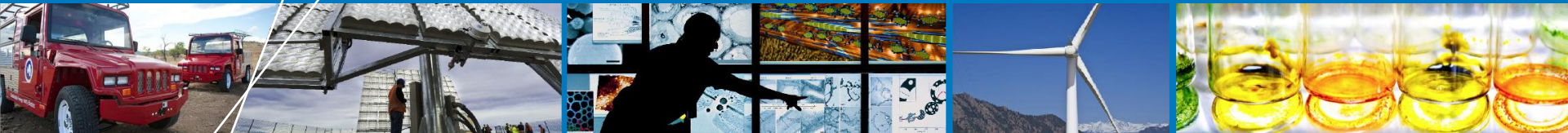


# PVWatts®: Tips and tricks for the latest update



**Nate Blair**

**July 9, 2014**

# What is STAT?

## Solar Technical Assistance Team (STAT)

- **U.S. Department of Energy (DOE) Solar Technologies Office, in coordination with the National Renewable Energy Laboratory (NREL)**
- **Objective**
  - Provide current, credible information on solar policy, program, and regulatory choices to entities positioned to impact the policy environment through:
    - Basic solar education for new officials and staff
    - Partnerships to address specific challenges
    - Topical learning opportunities



**To learn more, visit:**

**[http://www.nrel.gov/tech\\_deployment/stat.html](http://www.nrel.gov/tech_deployment/stat.html)**

# DIY Solar Market Analysis Summer Series

**2<sup>nd</sup> Wednesday of EVERY MONTH**  
**Noon – 1 pm MST**

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**Wednesday  
MAY 14th**

**Wednesday  
JUNE 11th**

**Wednesday  
JULY 9th**

**Wednesday  
AUGUST  
13th**

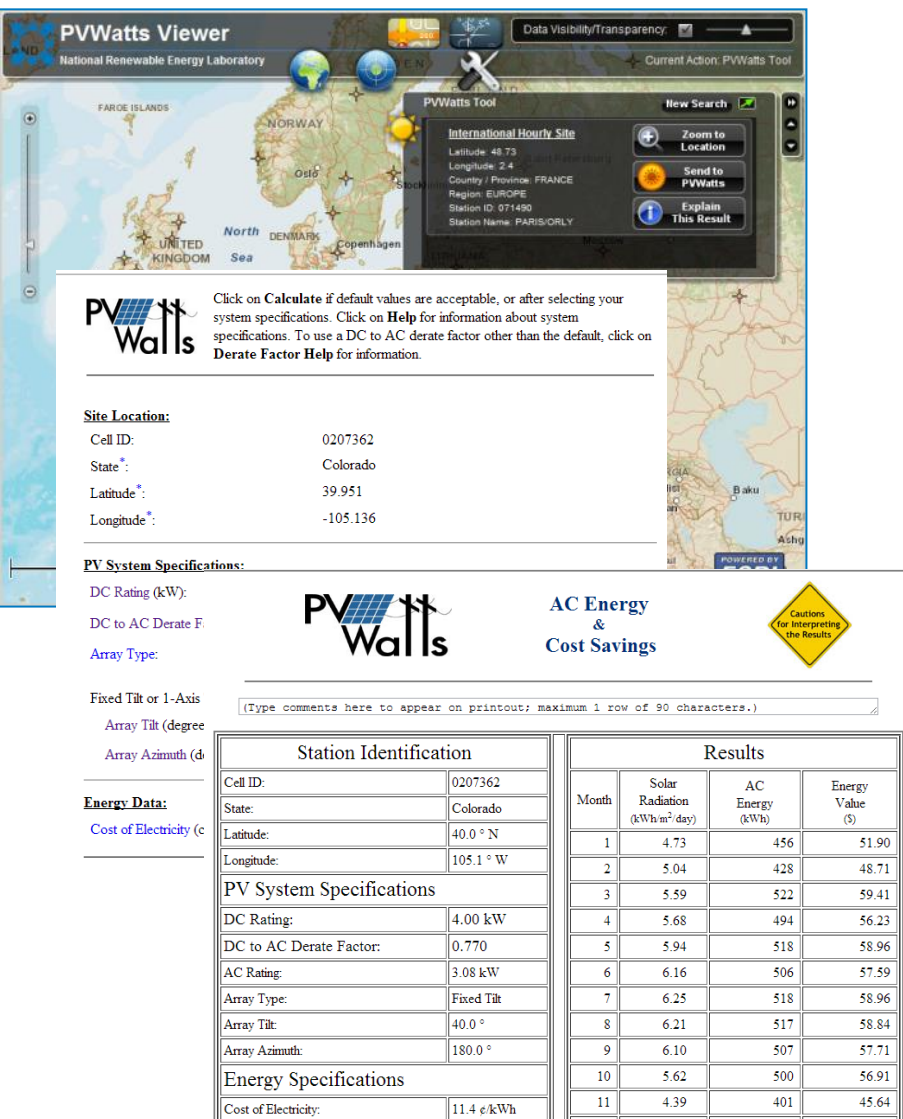
- 
- **Top Solar Tools:**  
What are they and how do they help policymakers?
  - **Solar Resource and Technical Potential:**  
Finding, using, and making maps for decision makers
  - **PVWatts: What's New?**  
Tips and tricks for the latest update
  - **Community Solar Scenario Tool:** Learn to evaluate if a solar garden makes sense in your community

[Subscribe here: http://www.nrel.gov/tech\\_deployment/stat\\_subscribe.html](http://www.nrel.gov/tech_deployment/stat_subscribe.html)

# Agenda for Today's Webinar

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- Basic Introduction to PVWatts
- Demonstration of Existing PVWatts options
  - Version 1 (specific sites using TMY2 weather data)
  - Version 2 (40km gridded data)
  - PVWatts Viewer
- Discussion of Recent and Ongoing Updates present in new version
- Walk through of new version (<http://pvwatts.nrel.gov>) including hints/tricks along the way



**PVWatts Viewer**  
National Renewable Energy Laboratory

Click on **Calculate** if default values are acceptable, or after selecting your system specifications. Click on **Help** for information about system specifications. To use a DC to AC derate factor other than the default, click on **Derate Factor Help** for information.

**Site Location:**

Cell ID: 0207362  
State: Colorado  
Latitude: 39.951  
Longitude: -105.136

**PV System Specifications:**

DC Rating (kW):  
DC to AC Derate F:  
Array Type:  
Fixed Tilt or 1-Axis  
Array Tilt (degree)  
Array Azimuth (d)

**Energy Data:**  
Cost of Electricity (c)

**Station Identification**

|            |           |
|------------|-----------|
| Cell ID:   | 0207362   |
| State:     | Colorado  |
| Latitude:  | 40.0 ° N  |
| Longitude: | 105.1 ° W |

**PV System Specifications**

|                         |            |
|-------------------------|------------|
| DC Rating:              | 4.00 kW    |
| DC to AC Derate Factor: | 0.770      |
| AC Rating:              | 3.08 kW    |
| Array Type:             | Fixed Tilt |
| Array Tilt:             | 40.0 °     |
| Array Azimuth:          | 180.0 °    |

**Energy Specifications**

|                      |            |
|----------------------|------------|
| Cost of Electricity: | 11.4 c/kWh |
|----------------------|------------|

**Results**

| Month | Solar Radiation (kWh/m <sup>2</sup> day) | AC Energy (kWh) | Energy Value (\$) |
|-------|--|-----------------|-------------------|
| 1     | 4.73                                     | 456             | 51.90             |
| 2     | 5.04                                     | 428             | 48.71             |
| 3     | 5.59                                     | 522             | 59.41             |
| 4     | 5.68                                     | 494             | 56.23             |
| 5     | 5.94                                     | 518             | 58.96             |
| 6     | 6.16                                     | 506             | 57.59             |
| 7     | 6.25                                     | 518             | 58.96             |
| 8     | 6.21                                     | 517             | 58.84             |
| 9     | 6.10                                     | 507             | 57.71             |
| 10    | 5.62                                     | 500             | 56.91             |
| 11    | 4.39                                     | 401             | 45.64             |

- A calculator for non-experts needing basic solar performance modeling on single structures
- Estimates hourly, monthly and annual PV electric output values
- Comprehensive US coverage and at selected international locations
- One of NREL's most heavily visited sites
- Version 1 launched in 1999
- Version 2 with 40k gridded data launched in 2005

# New PVWatts Release

<http://pvwattsbeta.nrel.gov>

- Updated web tools, etc. compliant with new web requirements
- Maintains goal of quick, accurate answers with minimal inputs
- Incorporates IMBY functionality:
  - Rooftop drawing tool
  - system costs, incentives, cost of energy calculation
  - 10km gridded solar data as an option
- Easy to build on in the future
- Switched from TMY2 weather data to closest TMY3 by default

The screenshot displays the PVWatts Calculator interface. The top navigation bar includes 'Get Started:', a location input field (set to 'Washington DC'), and buttons for 'Beta Release (?)', 'HELP', 'FEEDBACK', and 'ALL NREL SOLAR TOOLS'. The main content area is divided into 'RESOURCE DATA', 'SYSTEM INFO', and 'RESULTS' tabs. The 'SYSTEM INFO' tab is active, showing 'DC System Size (kW): 4' and a 'Draw Your System' button. The 'RESULTS' tab shows a total energy production of '4,763 kWh per Year'. Below this, a table provides monthly breakdowns of solar radiation, AC energy, and energy value.

| Month         | Solar Radiation (kWh / m <sup>2</sup> / day) | AC Energy (kWh) | Energy Value (\$) |
|---------------|--|-----------------|-------------------|
| January       | 3.13   | 299             | 35.86             |
| February      | 3.78   | 328             | 39.39             |
| March         | 4.67   | 437             | 52.48             |
| April         | 5.53   | 474             | 56.83             |
| May           | 4.70   | 403             | 48.42             |
| June          | 5.49   | 449             | 53.83             |
| July          | 5.42   | 451             | 54.12             |
| August        | 5.41   | 452             | 54.23             |
| September     | 5.00   | 418             | 50.15             |
| October       | 5.19   | 465             | 55.76             |
| November      | 3.28   | 289             | 34.70             |
| December      | 3.24   | 299             | 35.85             |
| <b>Annual</b> | <b>4.57</b>                                  | <b>4,763</b>    | <b>\$ 572</b>     |

Download Results: Monthly | Hourly

Caution: Photovoltaic system performance predictions calculated by PVWatts include many inherent assumptions and uncertainties and do not reflect variations between PV technologies nor site-specific characteristics except as represented by PVWatts inputs. For example, PV modules with better performance are not differentiated within PVWatts from lesser performing modules. See Help for additional guidance.

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# Key Model Changes

- Option to select between “Standard”, “Premium”, or “Thin-film” module type
- Option to specify a DC-to-AC nameplate sizing ratio
- System losses are specified as a percentage, default value of 14%. (replaces derate factor)
- Inverter performance curve updated
- One axis tracking systems either estimate linear beam+diffuse self-shading or use backtracking

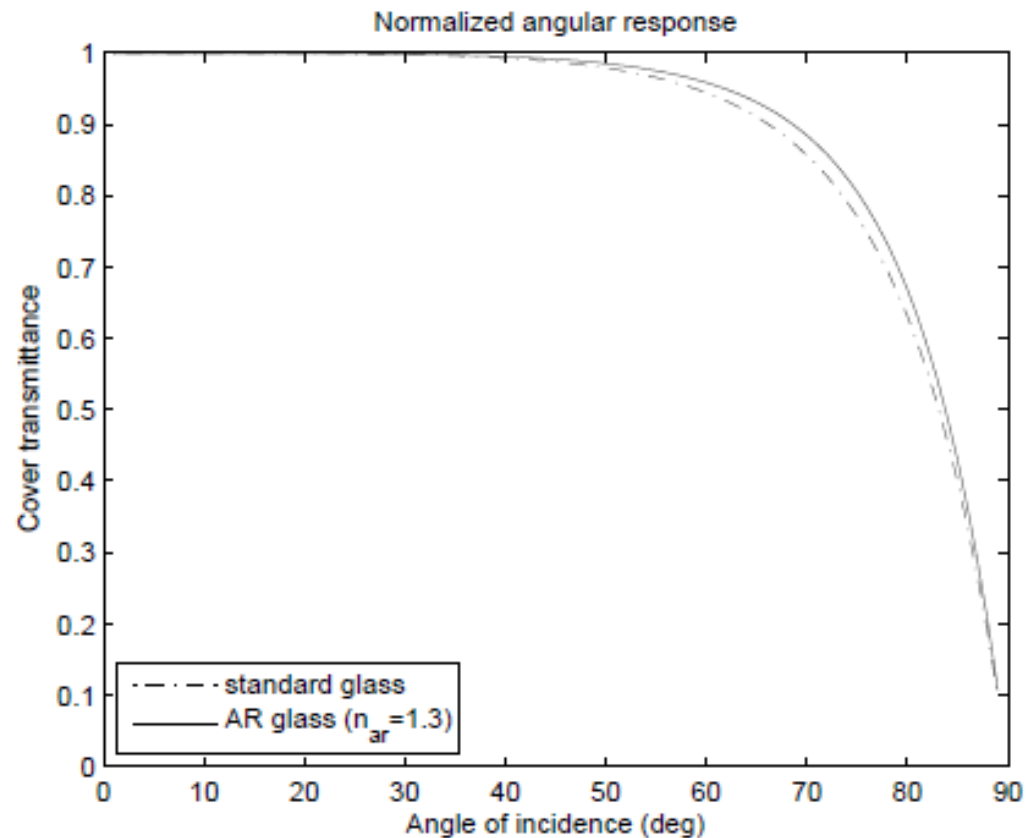
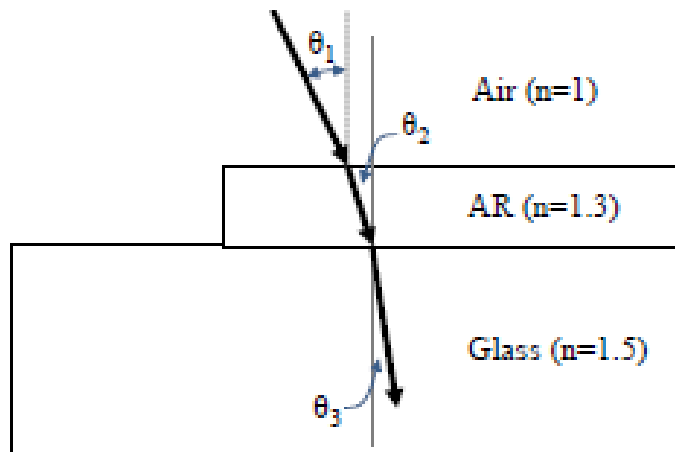
# Model Inputs

| Field                  | Units   | Default Value  |
|------------------------|---|--|
| System size            | kW (DC)   | 4  |
| Module type            | Standard, Premium, Thin film  | Standard   |
| System losses          | %   | 14   |
| Array type             | Fixed open rack, Fixed roof mount, 1-Axis, Backtracked 1-Axis, 2-Axis | Fixed open rack  |
| Tilt angle             | degrees   | Site Latitude  |
| Azimuth angle          | degrees   | 180° in northern hemisphere, 0° in southern hemisphere |
| <i>Advanced inputs</i> |   |  |
| DC/AC ratio            | ratio   | 1.1  |
| Inverter efficiency    | %   | 96   |
| GCR (1 Axis only)      | fraction  | 0.4  |

# Module Type

| Module type | Efficiency | Cover type      | Temperature coefficient |
|-------------|------------|-----------------|-------------------------|
| Standard    | ~15 %      | Glass           | -0.47 %/°C              |
| Premium     | ~19 %      | Anti-reflective | -0.35 %/°C              |
| Thin film   | ~10 %      | Glass           | -0.20 %/°C              |

## AR glass model



# Thermal Model

---

- **Fuentes 1986 heat transfer model as in V1**
- **Default open rack mounting system assumes INOCT=45 C**
  - 1 and 2 axis tracking makes open rack assumption
- **Fixed roof mount system assumes 4 inch standoffs, and reduced airflow results in higher INOCT = 49 C**

# System Losses

| Loss mechanism            | Default value |
|---------------------------|---------------|
| Soiling                   | 2 %           |
| Shading                   | 3 %           |
| Snow                      | 0 %           |
| Mismatch                  | 2 %           |
| Wiring                    | 2 %           |
| Connections               | 0.5 %         |
| Light-induced degradation | 1.5 %         |
| Nameplate rating          | 1 %           |
| Age                       | 0 %           |
| Availability              | 3 %           |
| Total losses              | 14 % (Eqn. 9) |

$$L_{total}(\%) = 100 \left[ 1 - \prod_i \left( 1 - \frac{L_i}{100} \right) \right]$$

To approximately convert a V5 system loss to a V1 DC-to-AC derate factor:

1. Convert the system loss to a derate:

$$1 - 14/100 = 0.86$$

2. Multiply this value by the nominal inverter efficiency:

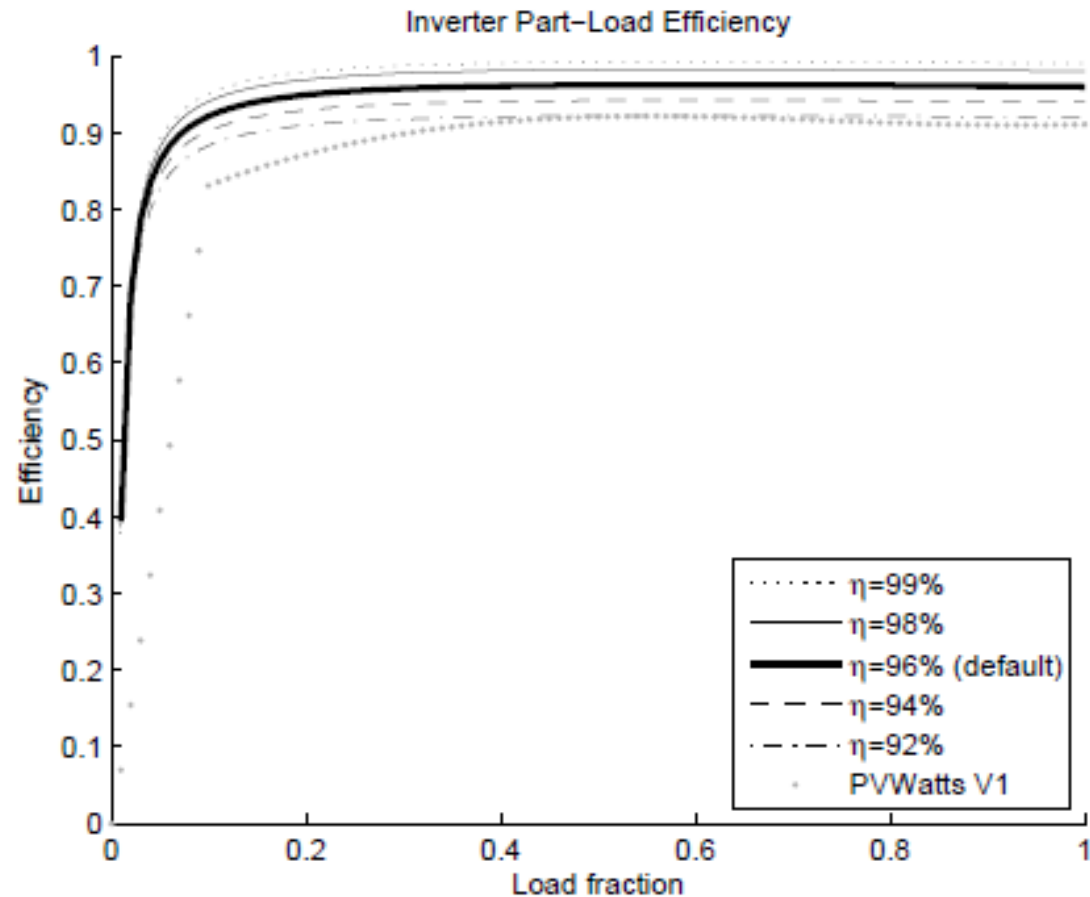
$$0.86 \times 0.96 = 0.825$$

The V5 is thus about 7 % higher than the V1 default of 0.77.

Energy prediction is actually about 8-9% higher due to the revised inverter performance curve.

# Inverter

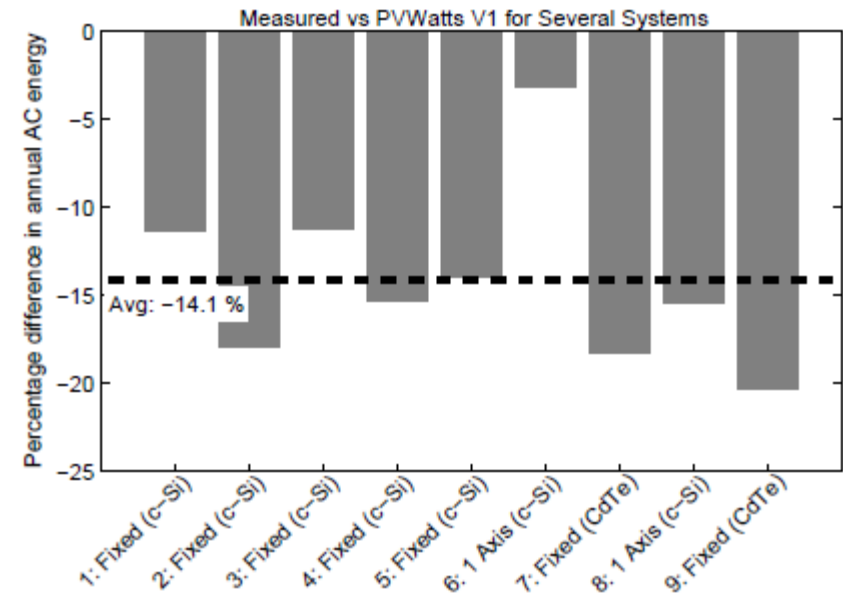
- Based on statistically most representative actual inverter in the CEC database since 2010
- Nominal efficiency can be set by the user, default is 0.96.



$$\eta = \frac{\eta_{nom}}{\eta_{ref}} \left( -0.0109 \cdot \zeta - \frac{0.0051}{\zeta} + 0.9888 \right) \quad \text{where} \quad \zeta = \frac{P_{dc}}{P_{dc0}} \quad \text{and} \quad P_{dc0} = \frac{P_{ac0}}{\eta_0}$$

# Comparison with Measured Data

- For nine systems, PVWatts V1 results show predictions are about 14% low
  - Unshaded systems, hours of bad data or when system is down are removed
- Zeroing out losses due to shading and availability, the effective V5 derate (slide 6) is 0.877, which is about 13.8 % higher than V1



# Comparison with V1 for 50 TMY2 sites

- V5 for fixed systems predicts about **7-9% more** energy than V1 with default inputs
- V5 one axis tracking predicts about **5% more** than V1: self shading or backtracking accounts for reduced relative improvement

| Location          | Fixed  | Fixed+Premium | 1 Axis | Backtracking | 2 Axis |
|-------------------|--------|---------------|--------|--------------|--------|
| AK Anchorage      | 14.7 % | 14.3 %        | 6.8 %  | 8.0 %        | 9.6 %  |
| AL Huntsville     | 9.7 %  | 11.2 %        | 4.9 %  | 5.9 %        | 8.5 %  |
| AR Little Rock    | 9.8 %  | 11.5 %        | 4.7 %  | 5.6 %        | 8.5 %  |
| AZ Phoenix        | 8.8 %  | 12.1 %        | 3.7 %  | 3.9 %        | 8.0 %  |
| CA Sacramento     | 9.2 %  | 11.2 %        | 4.0 %  | 4.5 %        | 8.2 %  |
| CO Boulder        | 8.9 %  | 10.2 %        | 3.3 %  | 3.9 %        | 7.3 %  |
| CT Hartford       | 10.2 % | 10.7 %        | 5.0 %  | 6.3 %        | 8.0 %  |
| DE Wilmington     | 9.9 %  | 10.8 %        | 4.9 %  | 5.9 %        | 8.3 %  |
| FL Miami          | 9.4 %  | 11.5 %        | 4.7 %  | 5.7 %        | 8.3 %  |
| GA Atlanta        | 9.5 %  | 11.0 %        | 4.6 %  | 5.4 %        | 8.4 %  |
| HI Honolulu       | 8.7 %  | 10.9 %        | 3.0 %  | 3.4 %        | 7.8 %  |
| IA Des Moines     | 9.6 %  | 10.3 %        | 4.2 %  | 4.9 %        | 8.0 %  |
| ID Boise          | 9.4 %  | 10.6 %        | 3.2 %  | 3.6 %        | 8.1 %  |
| IL Chicago        | 10.1 % | 10.7 %        | 4.7 %  | 5.7 %        | 8.4 %  |
| IN Indianapolis   | 10.0 % | 10.8 %        | 4.9 %  | 6.0 %        | 8.5 %  |
| KS Wichita        | 9.3 %  | 10.4 %        | 4.0 %  | 4.6 %        | 8.0 %  |
| KY Lexington      | 10.1 % | 11.0 %        | 5.0 %  | 6.0 %        | 8.7 %  |
| LA New Orleans    | 9.9 %  | 11.8 %        | 5.3 %  | 6.4 %        | 8.6 %  |
| MA Boston         | 9.8 %  | 10.2 %        | 4.7 %  | 5.7 %        | 8.0 %  |
| MD Baltimore      | 10.0 % | 10.9 %        | 4.9 %  | 5.9 %        | 8.4 %  |
| ME Portland       | 9.6 %  | 9.8 %         | 3.9 %  | 4.8 %        | 6.9 %  |
| MI Detroit        | 10.5 % | 10.9 %        | 4.9 %  | 6.1 %        | 8.2 %  |
| MN Minneapolis    | 9.5 %  | 9.8 %         | 3.7 %  | 4.5 %        | 6.9 %  |
| MO Springfield    | 9.6 %  | 10.8 %        | 4.4 %  | 5.1 %        | 8.3 %  |
| MS Jackson        | 9.8 %  | 11.6 %        | 5.2 %  | 6.2 %        | 8.5 %  |
| MT Great Falls    | 9.7 %  | 10.1 %        | 3.5 %  | 4.2 %        | 7.3 %  |
| NC Charlotte      | 9.7 %  | 11.2 %        | 4.9 %  | 5.8 %        | 8.5 %  |
| ND Fargo          | 9.6 %  | 9.6 %         | 3.3 %  | 4.1 %        | 6.6 %  |
| NE Omaha          | 9.5 %  | 10.4 %        | 4.2 %  | 5.0 %        | 7.5 %  |
| NH Concord        | 9.8 %  | 10.3 %        | 4.3 %  | 5.2 %        | 7.6 %  |
| NJ Newark         | 10.2 % | 10.8 %        | 5.3 %  | 6.4 %        | 8.6 %  |
| NM Albuquerque    | 8.5 %  | 10.3 %        | 3.6 %  | 4.0 %        | 7.6 %  |
| NV Las Vegas      | 8.5 %  | 11.2 %        | 3.0 %  | 3.1 %        | 7.8 %  |
| NY Albany         | 10.2 % | 10.6 %        | 4.4 %  | 5.4 %        | 8.0 %  |
| OH Cleveland      | 10.8 % | 11.4 %        | 5.3 %  | 6.5 %        | 8.6 %  |
| OK Tulsa          | 9.5 %  | 10.8 %        | 4.2 %  | 4.9 %        | 8.4 %  |
| OR Portland       | 11.6 % | 12.6 %        | 5.6 %  | 6.6 %        | 9.9 %  |
| PA Harrisburg     | 10.0 % | 10.9 %        | 5.0 %  | 6.0 %        | 8.6 %  |
| RI Providence     | 9.8 %  | 10.2 %        | 4.8 %  | 5.8 %        | 8.1 %  |
| SC Charleston     | 9.5 %  | 11.1 %        | 4.7 %  | 5.5 %        | 8.4 %  |
| SD Sioux Falls    | 9.6 %  | 10.1 %        | 3.8 %  | 4.5 %        | 7.1 %  |
| TN Chattanooga    | 10.1 % | 11.7 %        | 5.4 %  | 6.4 %        | 9.0 %  |
| TX Abilene        | 8.9 %  | 10.6 %        | 3.6 %  | 4.1 %        | 7.9 %  |
| UT Salt Lake City | 9.4 %  | 10.9 %        | 3.6 %  | 4.1 %        | 7.8 %  |
| VA Richmond       | 9.8 %  | 10.9 %        | 4.8 %  | 5.7 %        | 8.4 %  |
| VT Burlington     | 10.1 % | 10.3 %        | 4.1 %  | 5.1 %        | 7.4 %  |
| WA Yakima         | 9.8 %  | 11.2 %        | 3.3 %  | 3.7 %        | 8.1 %  |
| WI Madison        | 9.9 %  | 10.2 %        | 4.6 %  | 5.7 %        | 7.8 %  |
| WV Elkins         | 10.7 % | 11.3 %        | 5.9 %  | 7.4 %        | 9.0 %  |
| WY Cheyenne       | 8.8 %  | 9.2 %         | 2.9 %  | 3.4 %        | 7.2 %  |
| Average           | 9.8 %  | 10.9 %        | 4.4 %  | 5.3 %        | 8.1 %  |



# Map-Based Weather Data Selection

- Allows the user to visually select a weather file other than the default TMY3 file.
- Supports TMY2, TMY3, International files, and 10km gridded SolarAnywhere® by CPR® data.

**PVWatts® Calculator** **NREL**  
NATIONAL RENEWABLE ENERGY LABORATORY

My Location **chicago** Change Location Beta Release (?) **HELP** **FEEDBACK** **ALL NREL SOLAR TOOLS**

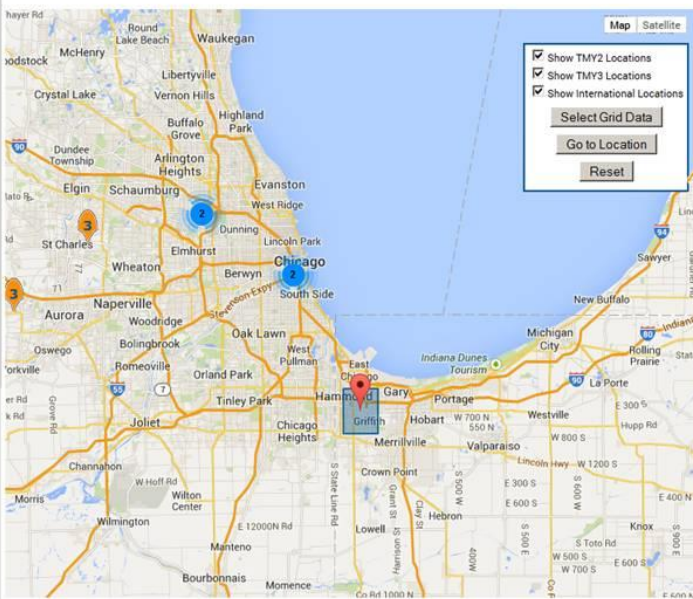
**RESOURCE DATA** **SYSTEM INFO** **RESULTS**

### SOLAR RESOURCE DATA

The recommended weather data source is listed below.

**Recommended weather data for your location**

**CHICAGO MIDWAY AP, ILLINOIS** 9.0 mi. **CHANGE**



Currently, PVWatts® defaults to the closest TMY3 weather file (or international file). This will be the standard for the foreseeable future. We also offer the TMY2 locations (which allow you to mimic PVWatts Version 1) and a 10k gridded data set from SolarAnywhere. We will not be including the older 40k gridded data from PVWatts Version 2 as the other datasets are superior. Click the "Change" button above to see what data is available for your location. Refer to [Help](#) for more detailed information.

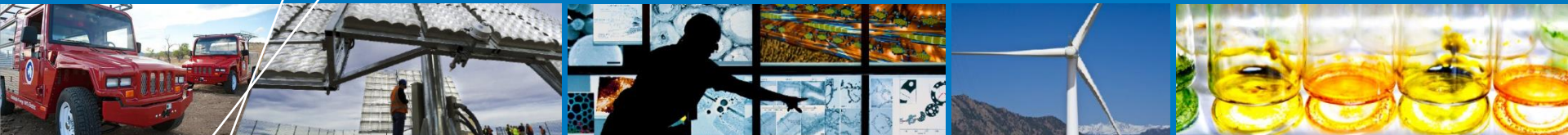
# General Deployment Plan

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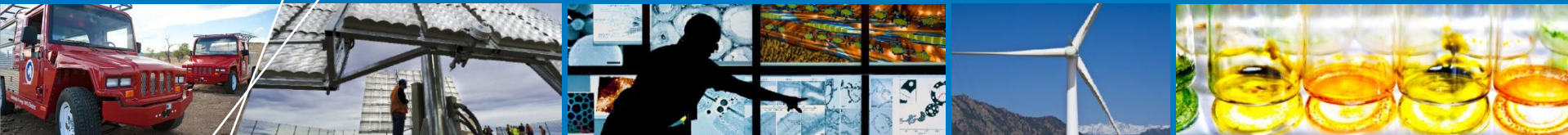
- Coding essentially complete
- Currently doing final internal and external reviews (industry reviews are positive)
- Update the website and web service for <http://pvwatts.nrel.gov> hopefully in July 2014
- Leave the old V1 and V2 sites running until end of calendar year to ease the transition to users

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# Questions?



**Thank You!**

**Nate.Blair@nrel.gov**